International Council for
the Exploration of the Sea

C.M. 1990/E:9
Marine Environmental
Quality Committee
Ref. G

LEVELS OF MERCURY IN FLOUNDER (*PLATICHTHYS FLESUS* L.) AND COD (*GADUS MORHUA* L.) CAUGHT DURING THE YEAR 1988 IN THE HVALER ARCHIPELAGO, SOUTHERN NORWAY.

by

Ingvild Marthinsen and Gro Staveland
Division of Marine Zoology and Chemistry
University of Oslo
P.O Box 1064 Blindern
0316 Oslo 3

ABSTRACT

The total concentration of mercury was determined in samples of 80 flounders (*Platichthys flesus* L.) and 100 cod (*Gadus morhua* L.). The fish were caught at five different localities near or in the relatively polluted Glomma estuary. A higher mercury concentration was found in flounder than in cod. The influence of the factors sex, season, and distance from the Glomma outlet on the mercury concentration in the two fish species was investigated using 1-way and 2-way ANOVA. Mercury levels in both flounder and cod in the area did not seem to be affected by locality or sex, since no significant main effects or interactions (locality and sex) were found. The only seasonal variation was revealed in flounder, with a significantly higher mercury level in the spring as compared to corresponding levels in the autumn. This pattern is probably connected with spawning. Most of the cod in the present study were immature, and this may partly explain the lack of seasonal variation in mercury concentration. A significant increase in mercury content with increasing age was found for both species. Generally, the mercury concentrations in both flounder and cod were far below the maximum permitted level in Norway.

INTRODUCTION

Fish accumulate mercury directly from food and the surrounding water (Bryan 1976; Rainbow 1985). Mercury bioaccumulates, and is toxic to the cell at quite low concentrations (Clark 1986; Lindberg *et al.* 1987). Further, mercury is transformed to a very toxic form, methyl mercury, in aquatic sediments. Major sources of mercury in coastal waters are rivers carrying industrial pollutants and wastes dumped directly into the sea (Clark 1986).

The Hvaler archipelago was monitored in the 1980's to study the extent of mercury pollution in fish (Knutzen 1984; Monfelt & Lindeström 1989). However, in these surveys little attention was paid on possible effects of season and sex on the mercury levels in fish. Besides, these studies did not include biological parametres like age, growth, gonad development etc. of the fish.

The present study is a survey of mercury pollution in two sedentary fish species stationed in or around the Glomma estuary in the Hvaler archipelago. Glomma is the largest river in Norway. Along its lower end, several factories are situated as well as a large garbage dump. A chlorine alkali factory is assumed to be the major source of mercury pollution of the river (Skei 1984; Monfelt & Lindeström 1989).

The main objective of the present study was to investigate the influence of sex, age, season, and distance from the Glomma outlet on the mercury concentration in flounder (*Platichthys flesus* L.) and cod (*Gadus morhua* L.) caught at five locations during the year 1988.

MATERIALS AND METHODS

Field collection

During 1988, 393 flounders (*Platichthys flesus*) and 457 cod (*Gadus morhua*) were collected at five different stations located close to the outlet of the Glomma river in the outer Oslofjord (Figure 1). The fish were caught monthly from March to December. For fish collection, trawls were used at stations 3, 4, and 5 while gill nets were used at stations 1 and 2. The fish were kept at -20 °C for up to two weeks before determination of sex, weight, length, gonad index, liver weight, and anomalies. Otoliths were removed for age determination (Christensen 1964; Williams & Bedford 1974). Individual fillets were removed and kept frozen until mercury analysis was performed. From the total fish sample, 80 flounders and 100 cod were selected in an effort to obtain fish of similar age groups, 4-6 years in flounder and 1-3 years in cod. The groups contained about equal numbers of males and females. The flounders were mature while most of the cod were immature. In addition, fillets of 15 flounders from station 1 in September and 16 cod from station 2 in October were selected in order to determine the effect of age on mercury concentration in the two species.

Analytical procedure

The total levels of mercury were determined in tissue samples of individual flounders and cod. The samples were digested in a mixture of nitric and perchloric acid in a temperature programmable aluminium block (Haugen *et al.* 1985). Maximum digesting temperature for the mercury determination was 190 °C. Mercury was determined with a hydride generator system producing a continuous, integratable signal. The detection limit was 0.02 mg/kg, when using about 1 g sample (Haugen *et al.* 1985).

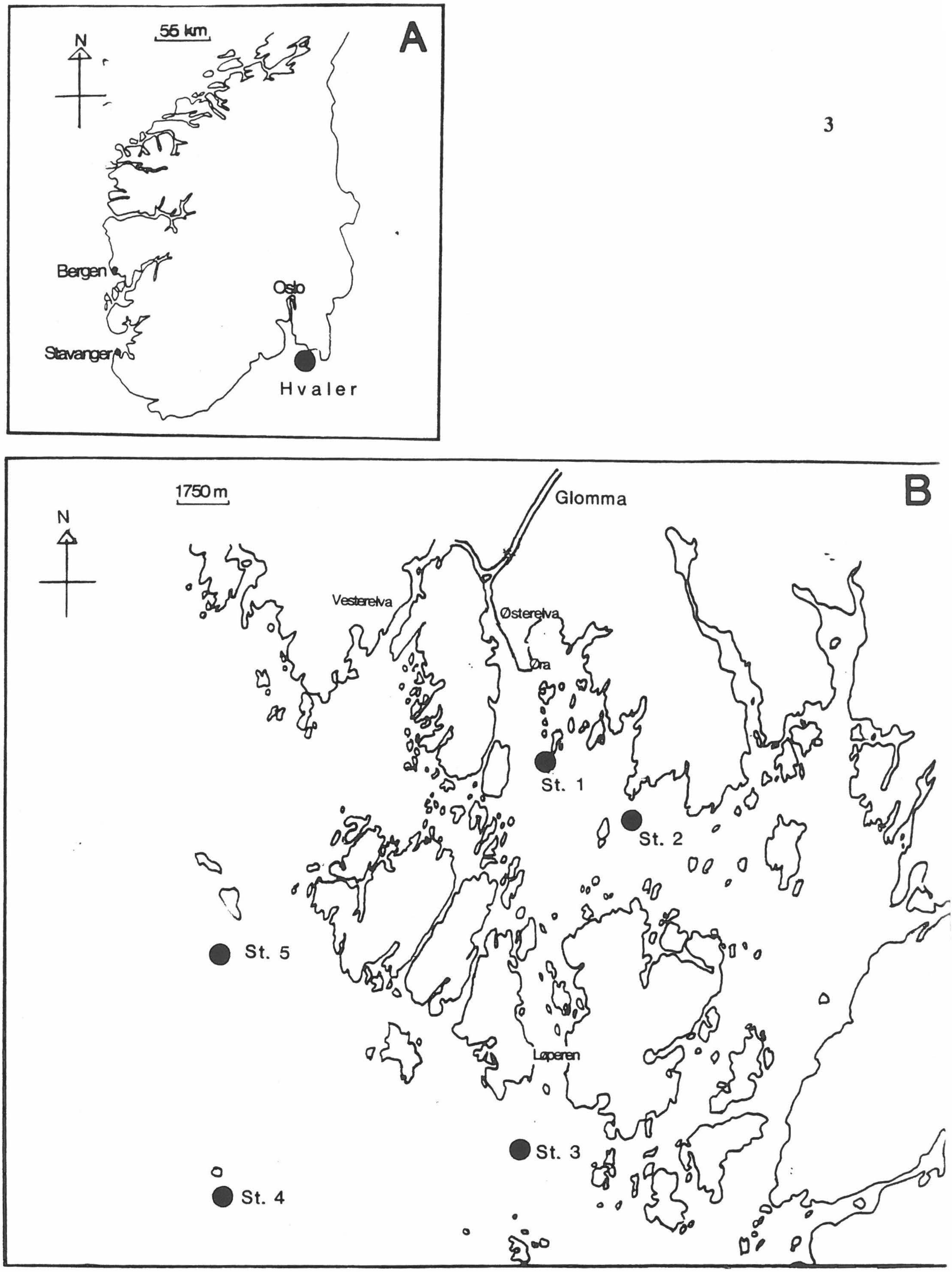

Figure 1. **A**. Map of the southern part of Norway indicating the location of the Hvaler archipelago. **B**. Map of the Hvaler archipelago with locations of the 5 sampling sites.

Statistical analysis

The three chosen factors; sampling site (i. e. station), season (i. e. sampling month), and sex might have a significant influence on the mercury concentration in the two fish species in the present study. In order to estimate the effects of the factors on the mercury concentration in the two fish species and their interactions, a 1-way and a 2-way ANOVA were used (Bhattacharyya & Johnson 1977). If the levels of a factor were found to be significantly different, they were ranked by Tukey's multiple comparison procedure (Larsen & Marx 1986). A simple linear regression was used to test the correlation between mercury content (depentent variable) and the age of the fish (independent variable) (Bhattacharyya & Johnson 1977). The results are given as arithmetic means ± standard error of the mean (SE).

RESULTS

Generally, flounder had a higher mean mercury concentration than cod (Table 1). A 2-way ANOVA showed no significant differences in mercury content between the stations 1-5 for neither flounder ($p>0.36$) nor cod ($p>0.12$).

Table 1. Mean mercury concentration (mg/kg wet weight) ± SE in flounder and cod from the stations 1-5. n indicates the total number of fish analyzed.

St	Flounder Mean Hg-level	n	Cod Mean Hg-level	n
1	0.15 ± 0.02	30	0.10 ± 0.01	10
2	0.19 ± 0.03	18	0.08 ± 0.01	20
3	0.14 ± 0.01	30	0.07 ± 0.01	30
4	0.12 ± 0.05	2	0.09 ± 0.01	20
5	-	-	0.09 ± 0.01	20

It was found that the male flounder had a slightly higher mean mercury level (0.17 mg/kg) than the female flounders (0.14 mg/kg), however, the difference was not statistically significant ($p>0.14$). In female and male cod the mean mercury levels were equal (0.09 mg/kg and 0.08 mg/kg, respectively). No significant interaction (at the 5 percent level) between the factors sex and station was found for either species.

For flounder, a significantly higher mean mercury content was obtained in March as compared to the corresponding level in September and November ($p<0.01$) (Figure 2). Seasonal variation in mercury concentration was not found for cod. In addition, no significant interaction between the factors sex and month was found for either species.

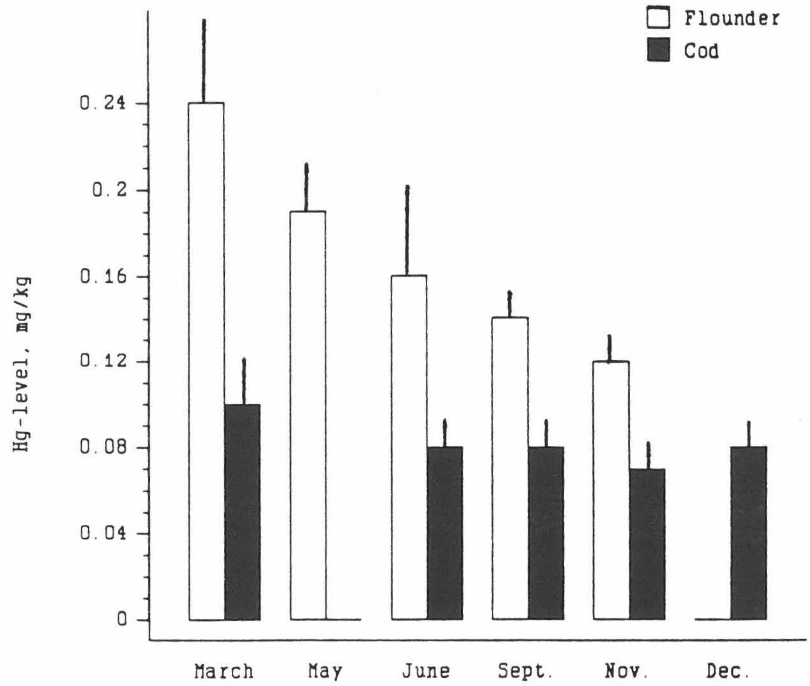

Figure 2. Seasonal variation in mean mercury concentration (mg/kg wet weight) ± SE in flounder and cod.

In both flounder and cod a significant increase in mercury concentration was observed with increasing age although few samples were analyzed ($p<0.05$, $r^2=0.27$, $y=0.02x + 0.02$ for flounder, and $p<0.02$, $r^2=0.32$, $y=0.13x - 0.13$ for cod) (Tables 2 and 3).

Table 2. Mean mercury concentration (mg/kg wet weight) ± SE in 1-9 year old flounders from station 1 in September. n indicates the total number of fish analyzed.

Age	Mean Hg level	n
1	0.07	1
4	0.06 ± 0.01	5
5	0.15 ± 0.04	4
6	0.16 ± 0.04	3
7	0.13	1
9	0.18	1

Table 3. Mean mercury concentration (mg/kg wet weight) ± SE in 1-3 year old cod from station 2 in October. n indicates the total number of fish analyzed.

Age	Mean Hg-level	n
1	0.10	1
2	0.10 ± 0.01	9
3	0.26 ± 0.07	6

DISCUSSION

Early in the 1980's, a mean mercury concentration of 0.3 mg/kg in flounder and 0.1 mg/kg in cod was found in the Hvaler archipelago (Knutzen 1984). The mean levels determined in flounder in the present study were considerably lower than those from Knutzen's survey, while the mean levels in cod were only slightly lower. A recent survey of flounder from the Hvaler archipelago, revealed mercury levels comparable to levels in the present study (0.07-0.17 mg/kg wet weight) (Monfelt & Lindeström 1989). The decrease observed in mean mercury level in flounder and to a certain extent in cod in the period 1980-1988, might reflect a decrease in mercury input from the chlorine alkali factory from about 1.1 tonn/year in 1974 to 40-50 kg/year in the 1980's.

The present mean mercury levels are much lower than corresponding levels in flounder and saithe (*Pollachius virens*) from the heavily polluted Sørfjorden (0.28-0.60 in flounder and 0.07-0.22 mg/kg in saithe) (Julshamn *et al.* 1985), which was also expected. However, the present mean mercury levels in cod are also lower than corresponding levels in cod from the North Sea (0.15-0.20 mg/kg), but higher compared to corresponding levels in cod from Greenland (0.01-0.04 mg/kg) (Clark 1986). It should however be pointed out that these studies do not specify the age of the fish. Since the age has an influence on the mercury concentration, and most of the cod in the present study were young, this may also explain the observed differences between their results and ours.

In Norway, the maximum permitted mercury intake is 0.3 mg/kg bodyweight/week for a grownup, which is in accordance with the recommendations from the FN organizations FAO and WHO (Clark 1986; Anon 1989). Generally, the mercury concentrations in both flounder and cod were far below the maximum permitted level in Norway.

The difference found in mean mercury levels between flounder and cod, may partly be caused by different behaviour and feeding habits. Flounder is a bottom dwelling fish in contact with sediment, whereas cod is a semipelagic species. Skurray & Cleary (1988) found a higher mercury level in bottom dwelling fish as compared to pelagic fish species, due to differences in feeding habits. Accumulation of mercury from food is predominant in aquatic organisms (Bryan 1976; Rainbow 1985). Mercury is also known to bioaccumulate in fish (Clark 1986; Lindberg *et al.* 1987), and since the flounders examined were older than the cod, this might also explain the observed difference.

The chlorine alkali factory situated at the lower reaches of the Glomma river, is assumed to be the major source of mercury pollution in the Hvaler archipelago. The sampling sites were selected to assess the possible influence by the Glomma watermasses from this factory. As a consequence, Næs (1983) and Knutzen (1984) found the highest mercury levels in sediments in Løperen and Vesterelva (see Figure 1). Further, they stated that the sediments in the area were only moderately contaminated by mercury due to a significant dilution effect by the Glomma river. The previous study revealed no significant difference in mercury concentration in fish caught at the inside and the outside of the islands for either species. Thus, fish close to the mercury source do not seem to be more exposed than fish far from the source in the Hvaler archipelago. Monfelt & Lindeström (1989) found a higher mercury level in flounder from the inside as compared to the outside of the islands. However, they did not state if their result was statistically significant. The Hvaler archipelago is heterogeneous both with regard to depth and salinity. This might lead to a difference in mercury availability between the inside and the outside of the islands. Many factors affect the availability of metals. The most important are metal-concentrations in solution and prey, temperature, pH and redox potential (Luoma 1983). Besides, mercury often forms complexes with chloride and bromide in sea water, which leads to a greater proportion of free mercury ions at low salinities (Phillips 1977; Rainbow 1985). The above mentioned factors together with a certain geographical variation in feeding habits found by Wigeland (1975), might lead to similar mercury levels in both flounder and cod on the inside and the outside of the Hvaler islands. Apart from this, migration between the stations might also play a part, even though both flounder and cod in the Oslofjord are thought to be stationary (Dannevig 1954; Hansen 1979).

The present study showed a seasonal variation in mercury content in flounder. This was not found for cod. Since the gonads contain more mercury than fish muscle (Vøllestad 1987), a seasonal variation in mercury level was expected for the mature fish. The flounders had a significantly higher mercury level in March, just before the spawning period, and a lower level in the autumn. Most of the cod in the present study were immature, and such a variation due to gonad development could not be expected.

Other studies have revealed differences in mercury content between the sexes (Phillips 1977; Clark 1986). This was not found in the present study for either species. Possible reasons may be differences between females and males with respect to feeding habits, behavioural pattern, and physiological status.

Methyl mercury has a long half life in fish. This leads to increasing concentrations with increasing age of the fish (Bryan 1976; Richards & Dulley 1983). A significant increase with increasing age was found for both species in the present study although the samples were small.

ACKNOWLEDGEMENTS

The authors express their thanks to Gunnar Norheim at the Department of Pharmacology and Toxicology, Norwegian College of Veterinary Medicine/National Veterinary Institute for mercury analysis and helpful discussions. The fish sampling was carried out with the finacial support of the Borgestad Legacy, University of Oslo, and the chemical analysis with financial support from the Norwegian Food Control Authority.

REFERENCES

Anon (1989). Evaluation of certain food additives and contaminants. Thirty-third Report of the Joint FAO/WHO Expert Comm. Food Add. Techn. Rep. Ser. 776.

Bhattacharyya G. K. & Johnson R. (1977). Statistical consepts and methods. John Wiley & Sons, New York. 639 pp.

Bryan G. W. (1976). Heavy metal contamination in the sea. In: Johnston R. (ed). Marine Pollution. Academic Press, London. 729 pp.

Christensen J. M. (1964). Burning of otoliths, a technique for age determinations of soles and other fish. J. Cons. Cons. Int. 'Explor. Mer. 29 (1), 73-81.

Clark R. B. (1986). Marine pollution. Claredon Press, Oxford. 215 pp.

Dannevig A. (1954). The littoral cod of the Norwegian Skagerak coast. Rapp. P. -V. Reun. Cons. Int. 'Explor. Mer. 136, 7-14.

Hansen Ø. K. (1979). Skrubba, *Platichthys flesus* (L.), i Oslofjorden og dens forhold til forurensing. Biologien til skrubba i Oslofjorden, med vekt på vekst- og forplantningsforhold. Cand. real. thesis, Univ. of Oslo. 85 pp.

Haugen A., Høie R. & Norheim G. (1985). Automated hydride generator determination of selenium and mercury in biological material. 10th Nordic Atomic Spectroscopy and Trace Element Conference, Turku, Finland 6-9 August 1985.

Julshamn K., Slinning K-E., Haaland H., Bøe B. & Føyn L. (1985). Analyse av sporelementer og klorerte hydrokarboner i fisk og blåskjell fra Hardangerfjorden og tilstøtende fjordområder høsten 1983 og våren 1984. Fiskeridir. Rap. og Meld. 16/85.

Knutzen J. (1984). Basisundersøkelser i Hvalerområdet og Singlefjorden. Miljøgifter i organismer 1980-1981. NIVA Rap. 122/84.

Larsen R. J. & Marx M. L. (1986). An introduction to matematical statistics and its applications. Prentice-Hall International, Inc., New Jersey. 625 pp.

Lindberg S., Stokes P. M., Goldberg E. & Wren C. (1987). Mercury. In: Hutchinson T. C. & Meema K. M. (ed). Lead, mercury, cadmium and arsenic in the environment. John Wiley & Sons Ltd, Chichester. 360 pp.

Luoma S. N. (1983). Bioavailability of trace metals to aquatic organisms - a review. Sci. Total Environ. 28, 1-22.

Monfelt C. & Lindeström L. (1989). Undersøkninger av skrubbskädda (*Platichtys flesus* L.) fångad i Hvaler- och Singlefjordsområdet hösten 1988. Svenska MiljöForskarGr. AB F9/037.

Næs K. (1983). Basisundersøkelser i Hvalerområdet og Singlefjorden. Løste metaller, suspendert materiale og sedimenter. NIVA Rap. 70/83.

Phillips D. J. H. (1977). The use of biological indicator organisms to monitor trace metal pollution in marine and estuarine environments. Environ. Pollut. 13, 281-317.

Rainbow P. S. (1985). The biology and heavy metals in the sea. Int. J. Environ. Stud. 25, 195-211.

Rickards D. G. & Dulley M. E. R. (1983). The levels of some heavy metals and chlorinated hydrocarbons in fish from the tidal Thames. Environ. Pollut. Ser. B. 5, 101-119.

Skei J. (1984). Basisundersøkelser i Hvalerområdet og Singlefjorden. Konklusjonsrapport. NIVA Rap. 171/84.

Skurray G. R. & Cleary A. (1988). Mercury levels in Australian seafood. ASEAN Food J. 4 (1), 41-42.

Vøllestad A. (1987). Kvikksølv i fisk i Østfold 1986. Fylkesm. i Østfold Miljøvernavd. Rap. 7.

Wigeland T. J. (1975). Skrubben, *Platichthys flesus* (L.), i Oslofjorden og dens forhold til forurensing. Ernæringsforhold hos skrubbe, *Platichthys flesus* (L.), på utvalgte lokaliteter i Oslofjorden. Cand. real. thesis, Univ. of Oslo. 137 pp.

Williams T. & Bedford B. C. (1974). The use of otoliths for age determination. In: Bagenal T. B. (ed.), The ageing of fish. Unwin Brothers Limited, England. 234 pp.